Heating systems in buildings — Method for calculation of system energy requirements and system efficiencies —

Part 4-3: Heat generation systems, thermal solar systems

The European Standard EN 15316-4-3:2007 has the status of a British Standard

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National foreword

This British Standard is the UK implementation of EN 15316-4-3:2007.

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A list of organizations represented on this committee can be obtained on request to its secretary.

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Systèmes de chauffage dans les bâtiments - Méthode de calcul des besoins énergétiques et des rendements des systèmes - Partie 4-3 : Systèmes de génération de chaleur, systèmes solaires thermiques

Heizsysteme in Gebäuden - Verfahren zur Berechnung der Energieanforderungen und Wirkungsgrade von Systemen - Teil 4-3: Wärmeerzeugungssysteme Thermische Solaranlagen

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Foreword

This document (EN 15316-4-3:2007) has been prepared by Technical Committee CEN/TC 228 “Heating systems in buildings”, the secretariat of which is held by DS.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by January 2008, and conflicting national standards shall be withdrawn at the latest by January 2008.

This document has been prepared under a mandate given to CEN by the European Commission and the European Free Trade Association (Mandate M/343), and supports essential requirements of EU Directive 2002/91/EC on the energy performance of buildings (EPBD). It forms part of a series of standards aimed at European harmonisation of the methodology for calculation of the energy performance of buildings. An overview of the whole set of standards is given in prCEN/TR 15615.

The subjects covered by CEN/TC 228 are the following:

— design of heating systems (water based, electrical etc.);

— installation of heating systems;

— commissioning of heating systems;

— instructions for operation, maintenance and use of heating systems;

— methods for calculation of the design heat loss and heat loads;

— methods for calculation of the energy performance of heating systems.

Heating systems also include the effect of attached systems such as hot water production systems.

All these standards are systems standards, i.e. they are based on requirements addressed to the system as a whole and not dealing with requirements to the products within the system.

Where possible, reference is made to other European or International Standards, a.o. product standards. However, use of products complying with relevant product standards is no guarantee of compliance with the system requirements.

The requirements are mainly expressed as functional requirements, i.e. requirements dealing with the function of the system and not specifying shape, material, dimensions or the like.

The guidelines describe ways to meet the requirements, but other ways to fulfil the functional requirements might be used if fulfilment can be proved.

Heating systems differ among the member countries due to climate, traditions and national regulations. In some cases requirements are given as classes so national or individual needs may be accommodated.

In cases where the standards contradict with national regulations, the latter should be followed.

EN 15316 *Heating systems in buildings — Method for calculation of system energy requirements and system efficiencies* consists of the following parts:

Part 1: General

Part 2-1: Space heating emission systems

Part 2-3: Space heating distribution systems

Part 3-1: Domestic hot water systems, characterisation of needs (tapping requirements)

Part 3-2: Domestic hot water systems, distribution

Part 3-3: Domestic hot water systems, generation

Part 4-1: Space heating generation systems, combustion systems (boilers)

Part 4-2: Space heating generation systems, heat pump systems

Part 4-3: Heat generation systems, thermal solar systems

Part 4-4: Heat generation systems, building-integrated cogeneration systems

Part 4-5: Space heating generation systems, the performance and quality of district heating and large volume systems

Part 4-6: Heat generation systems, photovoltaic systems

Part 4-7: Space heating generation systems, biomass combustion systems

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

Introduction

This European Standard presents methods for calculation of the thermal solar system input for space heating and/or domestic hot water requirements and the thermal losses and auxiliary energy consumption of the thermal solar system. The calculation is based on the performance characteristics of the products given in product standards and on other characteristics required to evaluate the performance of the products as included in the system.

This method can be used for the following applications:

— judging compliance with regulations expressed in terms of energy targets;

— optimisation of the energy performance of a planned heat generation system, by applying the method to several possible options;

— assessing the effect of possible energy conservation measures on an existing heat generation system, by calculating the energy use with and without the energy conservation measure – i.e. the energy savings of a thermal solar system is determined by the difference in the calculated energy performance of the building with and without the thermal solar system.

The user needs to refer to other European Standards or to national documents for input data and detailed calculation procedures not provided by this European Standard.

1 Scope

This European Standard is part of a series of standards on the method for calculation of system energy requirements and system efficiencies. The framework for the calculation is described in prEN 15603.

The scope of this specific part is to standardise the:

— required inputs,

— calculation method,

— required outputs,

for thermal solar systems (including control) for space heating, domestic hot water production and the combination of both.

The following typical thermal solar systems are considered:

— domestic hot water systems characterized by EN 12976 (factory made) or ENV 12977 (custom built);

— combisystems (for domestic hot water and space heating) characterized by ENV 12977 or the Direct Characterisation method developed in Task 26 'Solar Combisystems' of the IEA Solar Heating and Cooling programme;

— space heating systems characterized by ENV 12977.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 12976-2, *Thermal solar systems and components — Factory made systems — Part 2: Test methods*

EN ISO 7345:1995, *Thermal insulation — Physical quantities and definitions (ISO 7345:1987)*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in EN ISO 7345:1995 and the following apply.

3.1
aperture area
solar collector maximum projected area through which un-concentrated solar radiation enters the collector

3.2
auxiliary energy
electrical energy used by technical building systems for heating, cooling, ventilation and/or domestic hot water to support energy transformation to satisfy energy needs

NOTE 1 This includes energy for fans, pumps, electronics etc. Electrical energy input to the ventilation system for air transport and heat recovery is not considered as auxiliary energy, but as energy use for ventilation.

NOTE 2 In EN ISO 9488, the energy used for pumps and valves is called "parasitic energy".

3.3
back-up energy
source of heat, other than solar, used to supplement the output provided by the thermal solar system

NOTE In EN ISO 9488, the back-up energy is called auxiliary energy.

3.4
collector loop
circuit, including collectors, pump or fan, pipework and heat exchanger (if present), which is used to transfer heat from the collectors to the heat storage device

3.5
forced-circulation system
system which utilizes a pump or a fan to circulate the heat transfer fluid through the collector(s)

3.6
heat use for space heating and/or domestic hot water
heat input to the space heating system and/or the domestic hot water system to satisfy the energy needs for space heating and/or domestic hot water, respectively

NOTE 1 If the technical building system serves several purposes (e.g. space heating and domestic hot water) it can be difficult to split the energy use into that used for each purpose. It can be indicated as a combined quantity (e.g. energy use for space heating and domestic hot water).

NOTE 2 The heat use for space heating and/or domestic hot water is the sum of the energy needs and the system thermal losses of the space heating system and/or the domestic hot water system minus the recovered system thermal losses at the system boundary.

3.7
recoverable system thermal loss
part of the system thermal loss which can be recovered to lower either the energy need for heating or cooling or the energy use of the heating or cooling system

3.8
recovered system thermal loss
part of the recoverable system thermal loss which has been recovered to lower either the energy need for heating or cooling or the energy use of the heating or cooling system

3.9
solar collector
device designed to absorb solar radiation and to transfer the thermal energy so produced to a fluid passing through

3.10
solar combisystem
thermal solar system delivering energy to both domestic hot water and space heating

3.11
solar domestic hot water (DHW) system
thermal solar system delivering energy to domestic hot water

3.12
solar fraction
energy supplied by the solar part of a system divided by the total system heat use (without the generation system losses)

3.13
solar preheat system
thermal solar system to preheat water prior to its entry into any other type of water heater

3.14
solar space heating (SH) system
thermal solar system delivering energy to space heating

3.15
solar-only system
thermal solar system without any back-up heat source

NOTE In EN ISO 9488, the back-up energy is called "auxiliary energy".

3.16
solar-plus-supplementary system
thermal solar system which utilizes both solar and auxiliary energy sources in an integrated way and is able to provide a specified heating service independent of solar energy availability

3.17
system thermal loss
thermal loss from a technical building system for heating, cooling, domestic hot water, humidification, dehumidification, or ventilation or lighting that does not contribute to the useful output of the system

NOTE A system thermal loss can become an internal heat gain for the building if it is recoverable.

3.18
technical building sub-system
part of a technical building system that performs a specific function (e.g. heat generation, heat distribution, heat emission)

3.19
technical building system
technical equipment for heating, cooling, ventilation, domestic hot water, lighting and electricity production composed by sub-systems

NOTE A technical building system can refer to one or to several building services (e.g. heating system, heating and domestic hot water system).

3.20
thermal solar system
system composed of solar collectors and other components for the delivery of thermal energy

3.21
thermosiphon system
system which utilizes only density changes of the heat transfer fluid to achieve circulation between collector and storage device or collector and heat exchanger

3.22
zero-loss collector efficiency
efficiency of the collector, when the collector mean fluid temperature is equal to the ambient temperature

NOTE When using data from EN 12975 and EN 12976 test reports for the calculations described in this European Standard, one needs to be careful to use the right values, as these test reports use the definitions according to ISO.

4 Symbols and abbreviations

For the purposes of this document, the following symbols and units (Table 1) and indices (Table 2) apply.

Table 1 — Symbols and units

A	collector aperture area	m²
A_C*	effective collector loop area	m²
a_1	heat loss coefficient of solar collector	W/(m²·K)
a_2	temperature dependence of the heat loss coefficient	W/(m²·K^2)
a, b, c,d,e,f	correlation factors	-
C_S	heat capacity of the storage tank	MJ/K
E	solar irradiation in a tilted plane	kWh/m²
f_{aux}	fraction of the storage tank volume used for back-up heating	-
f_{sol}	solar fraction	%
f_{st}	storage tank capacity correction factor	-
I	solar irradiance on the collector plane	W/m²
IAM	collector incidence angle modifier	-
P	power	W
Q	quantity of heat	kWh
S	savings	
t	time, period of time	hours
U	heat loss coefficient	W/(m²·K)
U_C*	effective collector heat loss coefficient (related to effective collector aperture area)	W/(m²·K)
V	volume	litres
W	auxiliary (electrical) energy	kWh
x, y	dimensionless factors	-
ΔT	reference temperature difference	K
θ_a	average ambient air temperature over the considered period	°C
θ_{cw}	mains water temperature	°C
θ_e	outside air temperature over the considered period	°C
η	efficiency factor	-

Table 2 — Indices

0	base reference	nom	nominal
a	air	nrbl	non recoverable
an	annual	nrvd	non recovered
aux	auxiliary	out	output from system
avg	average	p	pump
bu	back up	par	performance indicator (Qpar)
cw	cold water	rbl	recoverable
d	performance indicator (Qd)	ref	reference
dis	distribution	rvd	recovered
e	external	set point	set point
H	space heating	sol	solar
in	input to system	St	storage
int	internal	Tot	total
loop	collector loop	us	use
ls	losses	W	domestic hot water
m	monthly		

5 Principle of the method

5.1 Building heat requirements influence the energy performance of a thermal solar system

The performance of a thermal solar system depends on the thermal use applied to the system. The thermal use applied to the thermal solar system is the heat requirements of the building, including the energy needs, the thermal losses from the emission systems (emitters) and the thermal losses from the distribution systems (pumps and pipes). In general, the higher the total thermal use applied to the thermal solar system is, the higher is the output of the thermal solar system. Therefore, before starting determination of the system output, it is necessary to know the energy use applied to the thermal solar system:

Energy use applied for the space heating system:

— required space heating needs (see EN ISO 13790);

— thermal losses from space heating emission (see EN 15316-2-1);

— thermal losses from space heating distribution (see EN 15316-2-3).

Energy use applied for the domestic hot water system:

— required energy for domestic hot water needs, including emission losses (see prEN 15316-3-1);

— thermal losses from domestic hot water distribution (see prEN 15316-3-2).

5.2 The thermal solar system influences the energy performance of the building

The influence of a thermal solar system on the energy performance of a building comprises:

— heat output of the thermal solar system to the distribution systems (for space heating and/or for domestic hot water), thus reducing the buildings consumption of other (e.g. conventionally generated) heat;

— recovered losses from the thermal solar system used for space heating, thus reducing the buildings consumption of heat for space heating;

— electricity to be supplied to the thermal solar system, thus increasing the buildings consumption of electricity;

— reduction of operation time of the conventional heating generator. In some cases, the conventional back-up heater can be turned off during summer, thus reducing stand-by thermal losses and auxiliary electricity consumption.

5.3 Performance of the thermal solar system

The performance of the thermal solar system is determined by the following parameters:

— product characteristics according to product standards: System performance indicators (annual back-up energy, solar fraction and annual auxiliary energy) or collector parameters (collector aperture area, zero-loss efficiency, heat loss coefficients etc.);

— storage tank parameters (type of storage tank, size etc.);

— collector loop thermal losses and thermal losses of the distribution between storage tank and back-up heater (length, insulation, efficiency etc.);

— control of the system (temperature difference, temperature set points etc.);

— climate conditions (solar irradiation, outdoor air temperature etc.);

— auxiliary energy of the solar collector pump and control units;

— heat use of the space heating distribution system;

— heat use of the domestic hot water distribution system (or solar combisystem).

5.4 Heat balance of the heat generation sub-system, including control

In order to respect the general structure of the system loss calculation, the performance of the thermal solar sub-system shall be characterised by the following input data:

— type and characteristics of the thermal solar system;

— location of the thermal solar system;

— type of control system;

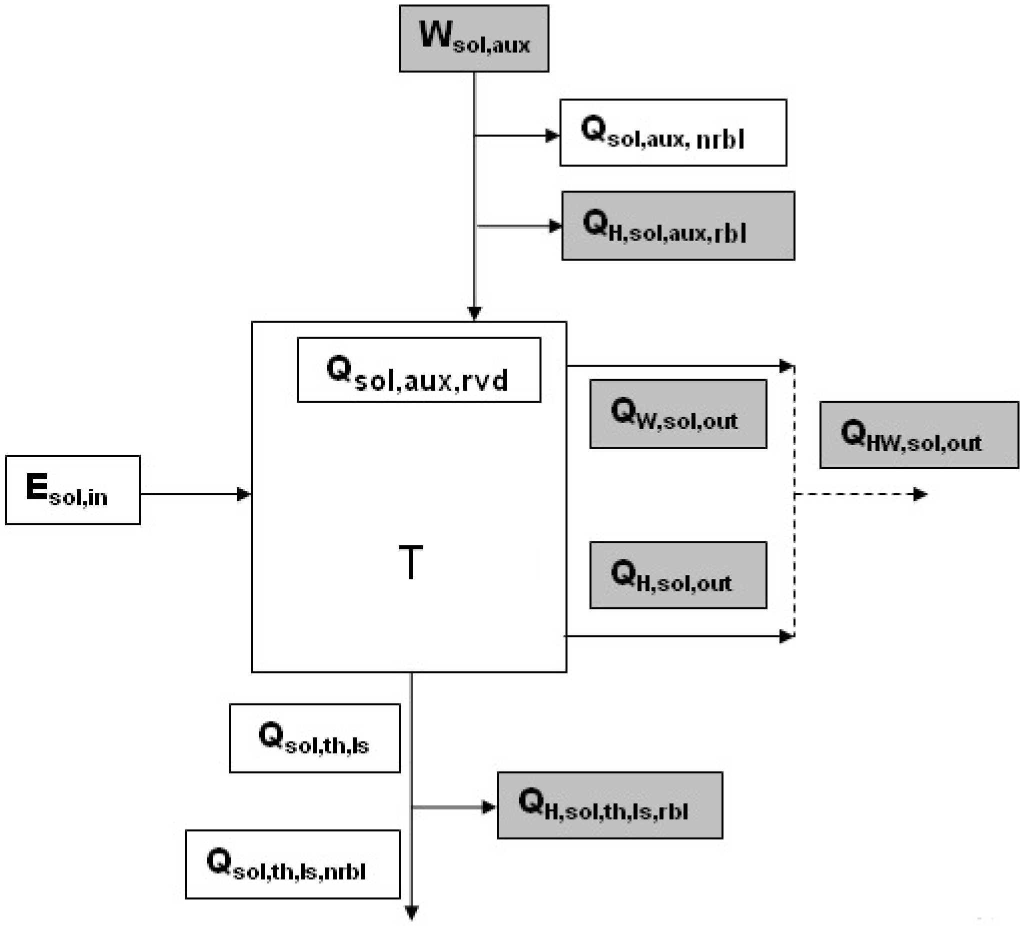
— heat use.

This European Standard requires input data according to other parts of this standard (see EN 15316-1 and prEN 15603).

Based on these data, the following output data are calculated in the thermal solar sub-system module:

- heat delivered by the thermal solar system;
- thermal losses of the solar storage tank;
- auxiliary energy consumption of pump and control equipment in the collector loop;
- recoverable and recovered auxiliary energy;
- recoverable and recovered thermal losses of the solar storage tank.

Heat balances of thermal solar systems are given in Figure 1 and Figure 2.

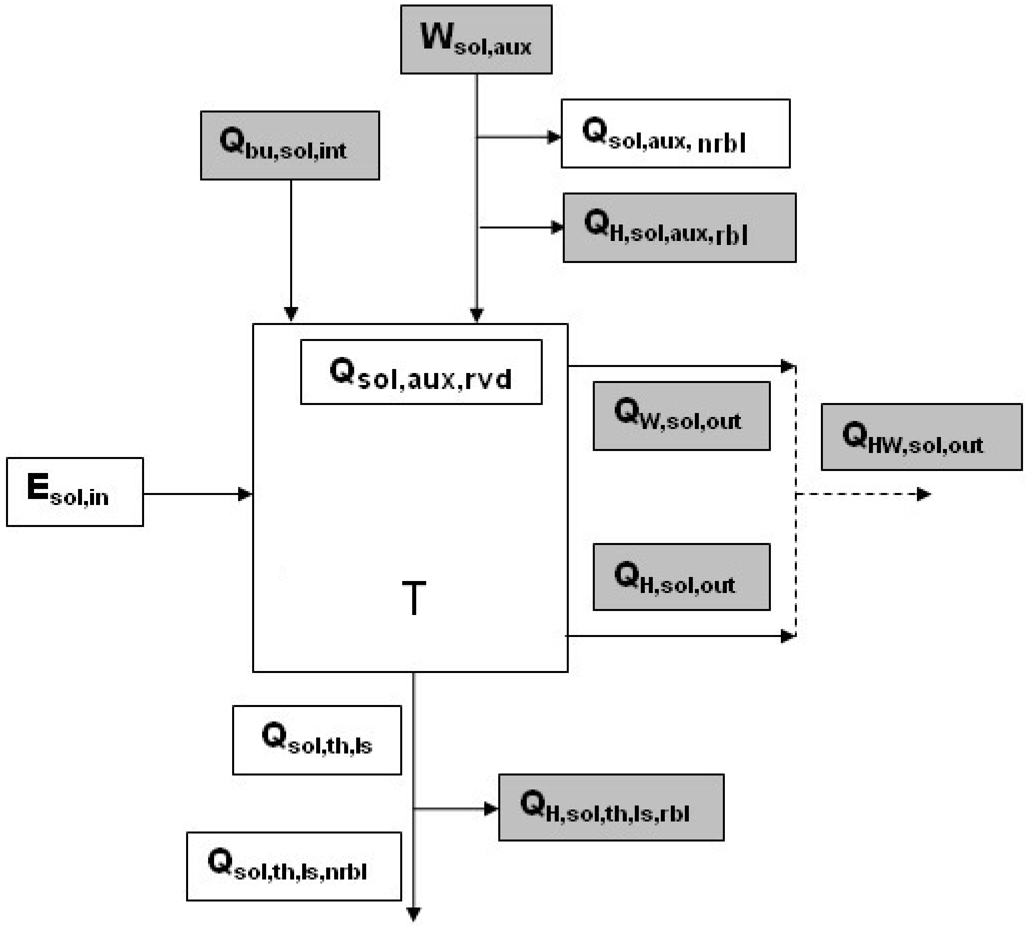


Key

T	thermal solar system
$E_{sol,in}$	incident solar energy on the plane of the collector array
$Q_{W,sol,out}$	heat delivered by the thermal solar system to domestic hot water distribution system
$Q_{H,sol,out}$	heat delivered by the thermal solar system to space heating distribution system
$Q_{HW,sol,out}$	total heat delivered by the thermal solar system to space heating and domestic hot water distribution system
$W_{sol,aux}$	auxiliary electrical energy for pumps and controllers
$Q_{H,sol,aux,rbl}$	recoverable auxiliary electrical energy for pumps and controllers. Part of the auxiliary electrical energy, which is recoverable for space heating
$Q_{sol,aux,rvd}$	internally recovered auxiliary electrical energy for pumps and controllers. Part of the auxiliary electrical energy, which is transferred as useful heat to the thermal solar system
$Q_{sol,aux,nrbl}$	non recoverable auxiliary electrical energy for pumps and controllers. Part of the auxiliary electrical energy, which is neither recoverable for space heating nor transferred as useful heat to the thermal solar system
$Q_{sol,th,ls}$	total thermal losses from the thermal solar system
$Q_{H,sol,th,ls,rbl}$	thermal losses from the thermal solar system, which are recoverable for space heating
$Q_{sol,th,ls,nrbl}$	non recoverable thermal losses from the thermal solar system. Part of the total thermal losses, which are not recoverable for space heating

Figure 1 — Heat balance for a solar preheat system / solar-only system

NOTE In case of a solar preheat system, the heat use for the external heat generator is reduced by $Q_{HW,sol,out}$



Key

T	thermal solar system
$E_{sol,in}$	incident solar energy on the plane of the collector array
$Q_{W,sol,out}$	heat delivered by the thermal solar system to domestic hot water distribution system
$Q_{H,sol,out}$	heat delivered by the thermal solar system to space heating distribution system
$Q_{HW,sol,out}$	total heat delivered by the thermal solar system to space heating and domestic hot water distribution system
$Q_{bu,sol,int}$	internal back-up heat input required
$W_{sol,aux}$	auxiliary electrical energy for pumps and controllers
$Q_{H,sol,aux,rbl}$	recoverable auxiliary electrical energy for pumps and controllers. Part of the auxiliary electrical energy, which is recoverable for space heating
$Q_{sol,aux,rvd}$	internally recovered auxiliary electrical energy for pumps and controllers. Part of the auxiliary electrical energy which is transferred as useful heat to the thermal solar system
$Q_{sol,aux,nrbl}$	non recoverable auxiliary electrical energy for pumps and controllers. Part of the auxiliary electrical energy, which is neither recoverable for space heating nor transferred as useful heat to the thermal solar system
$Q_{sol,th,ls}$	total thermal losses from the thermal solar system
$Q_{H,sol,th,ls,rbl}$	thermal losses from the thermal solar system, which are recoverable for space heating
$Q_{sol,th,ls,nrbl}$	non recoverable thermal losses from the thermal solar system. Part of the total thermal losses, which are not recoverable for space heating

Figure 2 — Heat balance for a solar-plus-supplementary system

5.5 Auxiliary energy

Auxiliary energy is required to operate the thermal solar sub-system, e.g. for the pump of the collector loop, for freezing protection. Auxiliary energy is accounted for in the generation sub-system as long as no transport energy is transferred to the distribution system outside the thermal solar sub-system.

In case of hydraulic decoupling between the generation and various distribution systems, e.g. by a buffer storage tank, the extra collector pump for storage loading is accounted for in the generation sub-system.

NOTE The term auxiliary energy used in this document is named parasitic energy in EN ISO 9488 (it comprises consumption of pumps, fans and control), while the term back-up used in this document is named auxiliary in EN ISO 9488.

5.6 Recoverable, recovered and unrecoverable thermal losses

The calculated thermal losses are not necessarily lost. Parts of the losses are recoverable, and parts of these recoverable losses are actually recovered.

Recoverable thermal losses $Q_{H,sol,th,ls,rbl}$ are e.g. the thermal losses from the distribution between the thermal solar sub-system and the back-up heater.

5.7 Calculation periods

The objective of the calculation is to determine the annual heat output of the thermal solar sub-system. This may be done in one of the following two different ways:

- by using annual data for the system operation period and performing the calculations using annual average values;
- by dividing the year into a number of calculation periods (e.g. months, operation periods as defined in EN ISO 13790), performing the calculations for each period using period-dependent values and sum up the results for all the periods over the year.

6 Thermal solar system calculation

6.1 Calculation procedures

In the following, two methods are given for determination of solar output, auxiliary energy consumption and recoverable losses from the thermal solar system and other output data related to the system and required for performing the energy performance calculation of a building with a thermal solar system.

The two methods enable the use of different type of input data:

- method A (see 6.2) uses system data, i.e. input data from system tests or default system input values given in the format of EN 12976-2 (performance indicators) – also system simulations (simulated tests) can be used;
- method B (see 6.3) uses component data, i.e. input data from component tests (or default component input values).

With method A, specific system parameters/characteristics (i.e. control strategies) can be better taken into account. Method B uses only test results (or default values) for components.

NOTE Method A can also be used for solar combisystems with collector areas smaller than 6 m^2. Limiting condition for testing these systems according to EN 12976-2 is that it is possible to test the domestic hot water function apart from the space heating function. In this case, system data only apply to domestic hot water, and thus space heating using the thermal solar system is not considered.

6.2 Method A - using system data (results from system tests)

6.2.1 General

This calculation method comprises the following steps:

- look up performance indicators in test results from test reports according to EN 12976-2;
- determine the solar output;
- determine the auxiliary energy consumption of the thermal solar system auxiliaries;
- calculate the system thermal losses of the thermal solar system:
  - determine the thermal losses of the solar storage tank;
  - determine the thermal losses of the distribution between the thermal solar system and the back-up heater;
- calculate the recoverable losses of the thermal solar system:
  - determine the recoverable auxiliary energy consumption;
  - determine the recoverable thermal losses of the solar storage tank;
  - determine the recoverable thermal losses of the distribution between the thermal solar system and the back-up heater.

NOTE 1 So far this method is only valid for systems delivering only domestic hot water and which have been tested according to EN 12976-2.

The test results shall include performance indicators for the actual climate and for a heat use higher than or equal to the actual heat use as well as for a heat use lower than or equal to the actual heat use.

NOTE 2 The intention is to make this method applicable also for systems, for which system parameters/characteristics are determined from recognised simulation tools.

6.2.2 Definition of heat use applied to the thermal solar system

The heat use applied to the thermal solar system depends on the thermal solar system configuration (preheat system, solar-plus-supplementary system, solar-only system).

In order to simplify and to avoid iterative calculation procedures, the following assumptions are made:

- for all configurations, the heat use to be applied shall take into account the needs (domestic hot water) and the thermal losses of the distribution system. The value of this heat use to be applied is an input data to this method;
- for a solar preheat system, the thermal losses between the thermal solar system and the back-up heater shall not be added to the heat use applied.
- thermal losses of the thermal solar system (losses from solar storage tank and solar collector loop) shall not be added to the heat use applied.

6.2.3 Output from thermal solar system

6.2.3.1 General

In order to determine the output from the thermal solar system, performance indicators according to EN 12976-2 shall be available for the system and the actual operation conditions.

Performance indicators for the actual climate and for a heat use higher than or equal to the actual heat use as well as for a heat use lower than or equal to the actual heat use shall be available.

6.2.3.2 Solar-only and solar preheat systems - determination of monthly solar output

The annual output $Q_{sol,out,an}$ of a solar-only system or a solar preheat system is calculated by:

$$Q_{sol,out,an} = f_{sol} \cdot Q_{sol,us,an} \quad \text{[kWh]} \tag{1}$$

where

f_{sol} is the solar fraction determined by interpolation to match the actual annual heat use applied (see below);

$Q_{sol,us,an}$ is the actual annual heat use applied to the solar system in kWh determined according to 6.2.2.

<u>Determination of f_{sol} for the actual heat use applied:</u>

$Q_{sol,us,an}$ given in kWh is converted to MJ to comply with the performance indicator Q_d calculated according to EN 12976-2:

$Q_d = Q_{sol,us,an} \cdot 3,6$

where

f_{sol} is determined by interpolation from test reports:

$$f_{sol} = f_{sol,i-1} + (f_{sol,i+1} - f_{sol,i-1}) \cdot (Q_d - Q_{d,i-1}) / (Q_{d,i+1} - Q_{d,i-1}) \quad [\%] \tag{2}$$

The indices i-1 and i+1 correspond to the nearest set of values below and above the actual value of Q_d (standard interpolation procedure).

<u>Determination of monthly output:</u>

The monthly outputs $Q_{sol,out,m}$ of the thermal solar system are assumed to be proportional to the monthly irradiance and are determined by:

$$Q_{sol,out,m} = Q_{sol,out,an} \cdot (I_m \cdot t_m) / (I_{an} \cdot t_{an}) \quad \text{[kWh]} \tag{3}$$

where

I_m is the average solar irradiance on the collector plane during the considered period. The values are defined in B.5; [W/m^2]

t_m is the length of the month in hours (28 days: 672 hours, 30 days: 720 hours, 31 days: 744 hours);

I_{an} is the average solar irradiance on the collector plane during the entire year. The values are defined in B.5; [W/m^2]

t_{an} is the length of the year in hours: t_{an} = 8760 hours.

Limitation of the thermal solar system output:

The thermal solar system output can not become negative: If the thermal solar system output determined above is negative, then the output is set equal to 0.

The thermal solar system output can not become higher than the heat use applied: If the thermal solar system output determined above is higher than the heat use applied, then the output is set equal to the heat use applied.

6.2.3.3 Solar-plus-supplementary system - determination of monthly solar output

The annual output $Q_{sol,out,an}$ of a solar-plus-supplementary system is calculated by:

$$Q_{sol,out,an} = Q_{sol,us,an} - Q_{bu,sol,int} \quad [kWh] \quad (4)$$

where

$Q_{sol,us,an}$ is the actual annual heat use applied to the system in kWh determined according to 6.2.2;

$Q_{bu,sol,int}$ is the energy demand of the heating system delivered by the back-up heater to the solar storage tank, determined by interpolation to match the actual heat use applied (see below).

Determination of $Q_{bu,sol,int}$ for the actual use applied:

$Q_{sol,us,an}$ given in kWh is converted to MJ to comply with the performance indicator Q_d calculated according to EN 12976-2:

$Q_d = Q_{sol,us,an} \cdot 3{,}6$

where

$Q_{bu,sol,int}$ is determined by interpolation from test reports:

$$Q_{bu,sol,int} = Q_{bu,sol,int,i-1} + (Q_{bu,sol,int,i+1} - Q_{bu,sol,int,i-1}) \cdot (Q_d - Q_{d,i-1}) / (Q_{d,i+1} - Q_{d,i-1}) \quad [kWh] \quad (5)$$

The indices i-1 and i+1 correspond to the nearest set of values below and above the actual value of Q_d (standard interpolation procedure).

Determination of monthly output:

The monthly outputs $Q_{sol,out,an}$ of the thermal solar system are assumed to be proportional to the monthly irradiance and are determined by:

$$Q_{sol,out,m} = Q_{sol,out,an} \cdot (I_m \cdot t_m) / (I_{an} \cdot t_{an}) \quad [kWh] \quad (6)$$

where

I_m is the average solar irradiance on the collector plane during the considered period. The values are defined in B.5; [W/m^2]

t_m is the length of the month in hours (28 days: 672 hours, 30 days: 720 hours, 31 days: 744 hours);

I_{an} is the average solar irradiance on the collector plane during the entire year. The values are defined in B.5; [W/m2]

t_{an} is the length of the year in hours: t_{an} = 8 760 hours.

Limitation of the thermal solar system output:

The thermal solar system output can not become negative: If the thermal solar system output determined above is negative, then the output is set equal to 0.

The thermal solar system output can not become higher than the heat use applied: If the thermal solar system output determined above is higher than the heat use applied, then the output is set equal to the heat use applied.

6.2.4 Auxiliary energy consumption of thermal solar system auxiliaries

Some thermal solar systems use auxiliary electrical energy (see 3.2) and some do not:

- for a thermosiphon system (self-circulation thermal solar system), auxiliary energy consumption is zero;
- for a forced circulation system, auxiliary energy consumption by pumps and controllers are taken into account.

NOTE Additional auxiliary energy consumption (e.g. for freezing protection) can be taken into account in national annexes.

The annual auxiliary energy consumption by pumps and controllers is taken from test reports for the performance indicator Q_{par} calculated according to EN 12976-2.

Interpolation to match the actual annual heat use applied is performed (corresponding to procedures given above for interpolation of performance indicators, see Equation (2) and Equation (5)). The value is then converted from MJ to kWh:

$$W_{sol,aux} = Q_{par} / 3{,}6 \qquad \text{[kWh]} \qquad (7)$$

where

Q_{par} is the annual auxiliary energy consumption in MJ by pumps and controllers determined by interpolation to match the actual annual heat use applied.

The monthly values of auxiliary energy consumption are determined by distribution of the annual auxiliary energy consumption corresponding to the monthly distribution of the solar irradiance from B.5 (e.g. if January irradiance is 5 % of annual irradiance, then January auxiliary energy consumption of the pump is 5 % of the annual auxiliary energy consumption of the pump).

6.2.5 System thermal losses

The system thermal losses are calculated according to 6.3.5 (method B).

6.2.6 Recoverable losses

The recoverable losses are calculated according to 6.3.6 (method B).

6.3 Method B - using component data (results from component tests)

6.3.1 General

This calculation method, based on the f-chart method (see [1]), comprises the following steps:

- define the use(s) applied to the thermal solar system (data input to this calculation):
  - calculate the ratio of space heating heat use applied to the total heat use applied (P_H);

  - calculate the ratio of domestic hot water heat use applied to the total heat use applied (P_W);
- calculate the ratio X (similar to a ratio of loss to heat use applied):
  - determine collector aperture area A;
  - determine heat loss coefficient of the collector loop U_{loop};
  - determine collector loop efficiency factor η_{loop};
  - calculate reference temperature difference ΔT;
  - calculate storage tank capacity correction factor f_{st} depending on the system configuration (preheat system or solar-plus-supplementary system);
  - attribute the solar storage tank volume to space heating or domestic hot water;
- calculate the ratio Y (similar to a ratio of solar output to heat use applied):
  - determine collector zero-loss collector efficiency factor η_0;
  - determine solar irradiance I on the collector plane;
- calculate the thermal solar output for space heating and for domestic hot water and the total thermal solar output;
- calculate the auxiliary energy consumption of the thermal solar system auxiliaries;
- calculate the system thermal losses of the thermal solar system:
  - determine the thermal losses of the solar storage tank;
  - determine the thermal losses of the distribution between the thermal solar system and the back-up heater;
- calculate the recoverable losses of the thermal solar system:
  - determine the recoverable auxiliary energy consumption;
  - determine the recoverable thermal losses of the solar storage tank;
  - determine the recoverable thermal losses of the distribution between the thermal solar system and the back-up heater.

6.3.2 Definition of heat use applied to the thermal solar system

The heat use applied to the thermal solar system depends on:

- the needs to satisfy (domestic hot water production and/or space heating);
- the thermal solar system configuration (preheat system, solar-plus-supplementary system, solar-only system).

In order to simplify and to avoid iterative calculation procedures, the following assumptions are made:

- for all building services, the heat use to be applied shall take into account the needs (e.g. building heat demand, domestic hot water) and the thermal losses of the distribution systems. The value of this heat use to be applied is an input data to this method;
- for a solar preheat system, the thermal losses between the thermal solar system and the back-up heater shall not be added to the heat use applied;
- thermal losses of the thermal solar system (losses from solar storage tank and solar collector loop) shall not be added to the heat use applied.

NOTE: In this method it is considered, that the back-up heater does not compensate the losses of the domestic hot water distribution.

6.3.3 Output from thermal solar system

6.3.3.1 Basic principles

For calculation of the output from the thermal solar system, three cases are distinguished:

a) only domestic hot water production

In this case, the output from the thermal solar system, $Q_{W,sol,out}$ is calculated with the following general calculation method (see 6.3.2.2) using only the applied domestic hot water use and the characteristics of the domestic hot water system (collector area, solar storage tank volume, etc.).

b) only space heating

In this case, the output from the thermal solar system, $Q_{H,sol,out}$ is calculated with the following general calculation method (see 6.3.3.2) using only the applied space heating use and the characteristics of the space heating system (collector area, solar storage tank volume, etc.).

c) solar combisystem (domestic hot water and space heating)

For a solar combisystem (see [2]), the solar output for domestic hot water production and the solar output for space heating requirements are calculated in succession with the following general calculation method (see 6.3.3.2). The method is applied twice by dividing the collector aperture area and the solar storage tank volume (if there is only one store) into two according to the space heating use ratio and the domestic hot water use ratio.

The total solar output is given by:

$$Q_{Tot,sol,out} = Q_{W,sol,out} + Q_{H,sol,out} \quad \text{[kWh]} \quad (8)$$

where:

$Q_{W,sol,out}$ heat delivered by the thermal solar system to domestic hot water distribution system [kWh]

$Q_{H,sol,out}$ heat delivered by the thermal solar system to space heating distribution system [kWh]

Dividing the collector aperture area

The general calculation of solar output (see 6.3.3.2) applies individually to solar output for space heating and solar output for domestic hot water, assuming that:

- one part of the collector aperture area is used for space heating and another part is used for domestic hot water, proportional to the space heating use and the domestic hot water use, respectively.

For determination of the parameters X, Y and f_{st}, the collector area is multiplied by the coefficient P_H in order to calculate output from the thermal solar system for space heating use ($Q_{H,sol,us}$) and the collector area is multiplied by the coefficient P_W in order to calculate output from the thermal solar system for domestic hot water use ($Q_{W,sol,us}$):

$$P_H = Q_{H,sol,us} / (Q_{H,sol,us} + Q_{W,sol,us}) \quad [-] \quad (9)$$

$$P_W = Q_{W,sol,us} / (Q_{H,sol,us} + Q_{W,sol,us}) \quad [-] \quad (10)$$

Dividing the solar storage tank volume:

For a one-tank system:

— storage tank volume used for calculation of the solar output for space heating is the volume of the solar storage tank multiplied by P_H;

— storage tank volume used for calculation of the solar output for domestic hot water is the volume of the solar storage tank multiplied by P_W.

If the system includes two solar storage tanks – one for space heating and one for domestic hot water – each of these is taken into account in the respective calculation (one storage tank may be a solar floor as in Annex B).

NOTE It is important to note, that calculation of storage tank volumes for space heating and domestic hot water is performed on a monthly basis. Otherwise the splitting-up according to heat use ratios will determine too small storage tank volumes for domestic hot water.

6.3.3.2 General calculation of solar output

The output of the thermal solar system is calculated, month by month, by:

$$Q_{sol,out,m} = (aY + bX + cY^2 + dX^2 + eY^3 + fX^3) \cdot Q_{sol,us,m} \quad [kWh] \quad (11)$$

where

$Q_{sol,us,m}$	is the monthly heat use applied to the thermal solar system The heat use to be applied for calculation of solar output is determined according to definitions above;	[kWh]
a, b, c, d, e,	are the correlation factors depending on storage tank type. The values, calculated in the f-chart method ([1]), are defined in B.1;	[-]
f	is the new correlation factor specific to direct solar floor ([3]). Value is defined in B.1;	[-]
X and Y	are dimensionless factors	[-]

Limitation of the thermal solar system output:

The thermal solar system output can not become negative: If the thermal solar system output determined above is negative, then the output is set equal to 0.

The thermal solar system output can not become higher than the heat use applied: If the thermal solar system output determined above is higher than the heat use applied, then the output is set equal to the heat use applied.

Determination of X:

The value X is calculated according to Equation (12). It depends on the collector loop heat loss coefficient and the temperature difference, but also on the storage tank volume taken into account by the storage tank capacity correction coefficient:

$$X = A \cdot U_{loop} \cdot \eta_{loop} \cdot \Delta T \cdot f_{st} \cdot t_m / (Q_{sol,us,m} \cdot 1\ 000) \quad [-] \quad (12)$$

where

A	is the collector aperture area according to EN 12975-2	[m²];
U_{loop}	is the heat loss coefficient of the collector loop (collector and pipes) / see Equation (13);	[W/(m²·K)]
η_{loop}	is the efficiency factor of the collector loop taking into account influence of heat exchanger. The value is defined in B.2;	[-]
ΔT	is the reference temperature difference / see Equation (14)	[K];
f_{st}	is the storage tank capacity correction factor. The values are given in B.3;	[-]
t_m	is the length of the month	[h];
$Q_{sol,us,m}$	is the monthly heat use applied to the thermal solar system according to definitions above.	[kWh]

The heat loss coefficient of the collector loop, collectors and pipes, is determined by the collector characteristics and the insulation of the pipes. The heat loss coefficient is calculated by:

$$U_{loop} = a_1 + a_2 \cdot 40 + U_{loop,p} / A \quad [W/(m^2 \cdot K)] \quad (13)$$

where

a_1 is the heat loss coefficient of solar collector related to the aperture area. This parameter is obtained according to EN 12975-2. Default values are given in B.2;

a_2 is the temperature dependence of the heat loss coefficient related to the aperture area. This parameter is obtained according to EN 12975-2. Default values are given in B.2;

$U_{loop,p}$ is the overall heat loss coefficient of all pipes in the collector loop, including pipes between collectors and array pipes between collector array and solar storage tank:

- if the pipe and insulation for the collector loop are known, then $U_{loop,p}$ can be calculated using the formulas for insulated pipes (see [1]);
- if the collector loop characteristics are not known, then $U_{loop,p}$ is to be determined according to B.2.

The reference temperature difference is calculated by:

$$\Delta T = \theta_{ref} - \theta_{e,avg} \quad [K] \quad (14)$$

where

θ_{ref} is the reference temperature depending on application and storage tank type, values are defined in B.4;

$\theta_{e,avg}$ is the average outside air temperature over the considered period, values are given in B.4.

Determination of Y

The value Y is calculated according to Equation (15). It depends on the collector data (zero-loss collector efficiency) and the solar irradiance on the collector plane:

$$Y = A \cdot IAM \cdot \eta_0 \cdot \eta_{loop} \cdot I_m \cdot t_m / (Q_{sol,us,m} \cdot 1\ 000) \quad [-] \quad (15)$$

where

A is the collector aperture area according to EN 12975-2 [m²];

IAM	is the incidence angle modifier of the collector = $K_{50}(\tau\alpha)$ from the collector test standard EN 12975-2. Default values are given in B.5;	[-]
η_0	is the zero-loss collector efficiency factor from the collector test standard EN 12975-2 and related to the aperture area. Default values are given in B.2;	[-]
η_{loop}	is the efficiency factor of the collector loop taking into account i nfluence of heat exchanger. The value is defined in B.2;	[-]
I_m	is the average solar irradiance on the collector plane during the considered period. The values are defined in B.5;	[W/m^2]
t_m	is the length of the month	[h];
$Q_{sol,us,m}$	is the monthly heat use applied to the thermal solar system according to definitions above	[kWh]

6.3.4 Auxiliary energy consumption of thermal solar system auxiliaries

Some thermal solar systems use auxiliary electrical energy (see 3.2) and some do not:

— for a thermosiphon system (self-circulation thermal solar system), auxiliary energy consumption is zero;

— for a forced circulation system, auxiliary energy consumption by pumps and controllers are taken into account.

Pumps

The auxiliary energy consumption by pumps in the thermal solar system is calculated by:

$$W_{sol,aux,m} = P_{aux,nom} \cdot t_{aux,m} / 1000 \quad \text{[kWh]} \qquad (16)$$

where

$P_{aux,nom}$	is the total nominal input power of pumps, i.e. the power stated on the pump's label. For a multi stage pump, the power corre-sponding to the typical operation mode is chosen. If the nominal power is not known, default values are given in B.2;	[W]
$t_{aux,m}$	monthly pump operation time.	[h].

The annual operation time according to EN 12976 is 2 000 h. The monthly operation time is determined by distribution of the annual operation time corresponding to the monthly distribution of the solar irradiance from B.5 (e.g. if January irradiation is 5 % of annual irradiation, then January operation time of the pump is 5 % of the annual operation time of the pump).

6.3.5 System thermal losses

6.3.5.1 Thermal losses of solar storage tank(s)

The thermal losses of solar storage tank(s) are determined by the overall heat loss coefficient U_{st} (W/K).

U_{st} can be obtained from test reports according to ENV 12977-3 or be determined as indicated in B.6.

For domestic hot water, monthly thermal losses are calculated by:

$$Q_{W,sol,st,ls,m} = U_{st} \cdot (\theta_{set\ point} - \theta_{a,avg}) \cdot (Q_{W,sol,out,m} / Q_{W,sol,us,m}) \cdot t_m / 1\,000 \quad \text{[kWh]} \qquad (17)$$

where

t_m is the length of the month [h];

$\theta_{set\ point}$ is the set point temperature of domestic hot water = 60°C;

$\theta_{a,avg}$ is the average ambient air temperature:

if the solar storage tank is installed in the heated space: $\theta_{a,avg}$ = 20 °C;

if the solar storage tank is installed in an un-heated space: $\theta_{a,avg} = \theta_{e,avg} + (20\ °C - \theta_{e,avg}) / 2$;

if the solar storage tank is installed outside: $\theta_{a,avg} = \theta_{e,avg}$ (see B.4).

For space heating, monthly thermal losses are calculated by:

$$Q_{H,sol,st,ls,m} = U_{st} \cdot (\theta_{set\ point} - \theta_{a,avg}) \cdot (Q_{H,sol,out,m} / Q_{H,sol,us,m}) \cdot t_m / 1\ 000 \quad [kWh] \quad (18)$$

where

$\theta_{set\ point}$ is the set point temperature: mean temperature of the space heating distribution system under design conditions (this is an input data to this method).

6.3.5.2 Thermal losses of the distribution between the thermal solar system and the back-up heater

Calculation of the thermal losses $Q_{bu,dis,ls,m}$ of the distribution between the thermal solar system and the back-up heater is given in B.7.

6.3.5.3 Total system thermal losses from the thermal solar system

The total system thermal losses from the thermal solar system are calculated, month by month, by:

$$Q_{sol,ls,m} = Q_{W,sol,st,ls,m} + Q_{H,sol,st,ls,m} + Q_{bu,dis,ls,m} \quad [kWh] \quad (19)$$

6.3.6 Recoverable losses

6.3.6.1 Recoverable auxiliary energy consumption

The recoverable part of the auxiliary energy consumption $Q_{sol,aux,rbl}$ is defined in B.8.

6.3.6.2 Recoverable thermal losses from solar storage tank(s)

The recoverable part of the thermal losses from the solar storage tanks $Q_{sol,st,ls,rbl}$ is defined in B.8.

6.3.6.3 Recoverable thermal losses from the distribution between the thermal solar system and the back-up heater

The recoverable part of the thermal losses from the distribution between the thermal solar system and the back-up heater $Q_{bu,dis,ls,rbl}$ is defined in B.8.

6.3.6.4 Total recoverable losses from the thermal solar system

The total recoverable losses from the thermal solar system are calculated, month by month, by:

$$Q_{sol,ls,rbl,m} = Q_{sol,aux,rbl,m} + Q_{sol,st,ls,rbl,m} + Q_{bu,dis,ls,rbl,m} \quad (20)$$

Other recoverable losses are treated in other parts of this standard:

- recoverable losses from domestic hot water emission and distribution system;
- recoverable losses from space heating emission and distribution system;
- recoverable losses from separate back-up heater(s).

6.3.7 Determination of reduced operation time of non-solar heat generator(s)

6.3.7.1 General

A thermal solar system reduces operation time of other (back-up) heat generator(s). This influences auxiliary energy consumption and in some cases thermal losses of the non-solar heat generator and hence the energy performance of the building due to:

— reduced auxiliary energy consumption;

— reduced stand-by thermal losses.

6.3.7.2 Reduction of auxiliary energy consumption of back-up heat generator(s)

It is assumed, that the auxiliary energy consumption of the back-up heat generator(s) is reduced proportional to the fraction of the heat use covered by the thermal solar system. This solar fraction is given month by month, by:

$$f_{sol,m} = Q_{sol,out,m} / Q_{sol,us,m} \qquad (21)$$

The reduced auxiliary energy consumption of the non-solar (back-up) heat generator(s), taking into account the thermal solar system, is given by:

$$W_{bu,aux,m} = W_{bu,nom,m} \cdot (1 - f_{sol,m}) \qquad (22)$$

where

$W_{bu,nom,m}$ is the monthly nominal [1] auxiliary energy consumption of the non-solar (back-up) heat generator(s) [kWh].

6.3.7.3 Reduction of thermal losses from back-up heat generator(s)

If the thermal solar system for a longer period covers the total use, the non-solar (back-up) heat generator(s) can be turned off and thermal losses from it are saved. However, in doing so, microbiological safety of the domestic hot water shall be guaranteed at any time.

It is assumed, that the non-solar (back-up) heat generator(s) cannot be turned off for a “longer period” if the fraction of the heat use covered by the thermal solar system (on a monthly basis) is less than 80 % of the total heat use.

It is assumed, that the non-solar (back-up) heat generator(s) can be turned off for a period proportional to the fraction of the heat use covered by the thermal solar system (on a monthly basis), if this fraction is 80 % or more.

Using the definition of $f_{sol,m}$ above, the reduced thermal losses from the non-solar (back-up) heat generator(s), taking into account the thermal solar system, are calculated by:

$$f_{sol,m} < 80\ \% \Rightarrow \quad Q_{bu,ls,m} = Q_{bu,ls,nom,m}$$

$$f_{sol,m} \geq 80\ \% \Rightarrow \quad Q_{bu,ls,m} = Q_{bu,ls,nom,m} \cdot (1 - f_{sol,m})$$

where

$Q_{bu,ls,nom,m}$ is the “nominal”[2] monthly thermal losses from the non-solar (back-up) heat generator(s) [kWh].

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[1] The ”nominal” auxiliary energy consumption is defined as the auxiliary energy consumption of the non-solar heat generator(s) in the case of no thermal solar system.

[2] The ”nominal” thermal losses are defined as the thermal losses from the non-solar heat generator(s) in the case of no thermal solar system.

Annex A
(informative)

Examples on determination of thermal performance of thermal solar systems

A.1 General

This annex elucidates the use of calculation method B as decribed in 6.3:

— for a solar DHW preheat system;

— for a solar combisystem.

For these two systems, major characteristics have been described as well as the way to determine their thermal performance.

A.2 Solar domestic hot water preheat system

A.2.1 General

The first example presents a solar DHW system with a solar collector measured according to EN12975-2 with an area of 2,702 m^2, a zero-loss collector efficiency factor of 0,8026 and a first order heat loss coefficient of 3,723 W/(m^2K) and a second order heat loss coefficient of 0,0135 W/(m^2K^2). In the drainback collector loop, there is a pump with nominal power of 50 W. After filling the collector loop, the pump switches back to a power of 20 W. The solar storage tank has an internal collector-side heat exchanger and direct tap water draw-off. The solar storage tank volume according to the specifications of the manufacturer is 120 litres. The solar storage tank and pump are located in the first floor, which is a heated part of the house. The heating season is from October up to and including March. The external back-up heater is always standby. Pipes between the solar storage tank and the back-up heater are insulated. Mains pressure is used for transport of tap water through solar DHW system and its back-up heater.

The objective is to determine the thermal performance of this solar DHW system for a hot water demand of 110 litres per day based on a temperature step from 15 °C to 65 °C, for location De Bilt, The Netherlands. The collector has a tilt of 45° and is facing South. Table A.1 lists the monthly values of average outside air temperature and solar irradiance and irradiation in the collector plane. Yearly average cold water temperature is 12 °C.

Table A.1 — Monthly values of average outside air temperature and solar irradiance and irradiation in a plane with a tilt of 45° facing South for Test Reference Year De Bilt, The Netherlands

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
θ_o [°C]	2,5	2,7	5,6	8,0	11,9	15,5	17,0	16,4	13,8	11,2	6,0	3,4
I [W/m^2]	40	65	126	167	193	209	187	206	139	94	51	33
$E_{sol,in}$ [kWh/m^2]	30	44	94	120	143	151	139	154	100	70	37	25

Calculation of the thermal performance follows the steps given in 6.3.

A.2.2 Determination of the heat use to be applied

First of all, the domestic hot water use is determined. The daily hot water use is 110 litre × 1 kg/litre × 4 180 J/(kgK) × 50 K = 6,39 kWh/day. In this example, thermal losses of the pipes between back-up heater and tapping points are 10% of the heat use applied, corresponding to 0.64 kWh/day. According to 6.3.2, thermal losses between solar storage tank and back-up heater shall not be taken into account. Table A.3 lists the monthly domestic hot water use.

A.2.3 Determination of system data

Most system data needed for determination of X, Y and $Q_{W,sol,out}$ are available. The storage tank capacity correction factor should be calculated: f_{st} = ((2,702 m^2 × 75 litre/m^2)/120 litre)^{0,25} = 1,14. The collector loop efficiency factor is not known; it is taken from B.2. The unknown overall heat loss coefficient of the collector loop pipes is also taken from B.2. Then, the value of U_{loop} can be calculated as 3,723 + 0,0135 · 40 + (5 + 0,5 · 2,702)/2,702 = 6,613 W/(m^{2}K). Table A.2 lists all characteristics needed for the calculation of the thermal solar system output.

Table A.2 — System characteristics for calculation of the thermal solar system output

solar collector		collector loop		solar storage tank	
A	2,702 m^2	η_{loop}	0,9	V_{sol}	120 litres
η_0	0,802 6	$P_{aux,nom}$	20 W	f_{st}	1,14
IAM	0,94				
U_{loop}	6,613 W/(m^{2}K)				

A.2.4 Determination of X, Y and thermal solar system output

Values of X, Y and $Q_{W,sol,out,m}$ are calculated for each month using the monthly domestic hot water use and the system characteristics as listed in Table A.2. The value of $Q_{W,sol,out,m}$ in January is -20 kWh, in November -2 kWh and in December -27 kWh; these values are set to zero. The annual system output is 950 kWh.

Table A.3 — Monthly values of the domestic hot water use, X, Y and thermal solar system output for the solar DHW preheat system

	$Q_{W,sol,us,m}$ [kWh]	X [-]	Y [-]	$Q_{W,sol,out,m}$ [kWh]
Jan	218	6,22	0,249	0
Feb	197	6,19	0,409	9
Mar	218	5,77	0,791	78
Apr	211	5,43	1,048	113
May	218	4,85	1,208	142
Jun	211	4,33	1,312	154
Jul	218	4,12	1,174	145
Aug	218	4,20	1,293	158
Sep	211	4,58	0,873	98
Oct	218	4,96	0,587	53
Nov	211	5,71	0,320	0
Dec	218	6,09	0,208	0
Year	**2 564**			**950**

A.2.5 Determination of the auxiliary energy consumption

The auxiliary energy consumption of the pump in the collector loop is calculated according to Equation (16) where the pump power is 20 W and the annual pump operation time is 2 000 h distributed over the months according to the solar irradiation in Table A.1. Values for the auxiliary energy consumption are listed in Table A.4. The annual total is 40 kWh.

Table A.4 — Monthly values of the auxiliary energy consumption of the pump in the collector loop

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
$W_{sol,aux,m}$ [kWh]	1,1	1,6	3,4	4,3	5,2	5,5	5,0	5,6	3,6	2,5	1,3	0,9	**40**

A.2.6 Determination of the thermal losses of the thermal solar system

The overall heat loss coefficient has not been measured, hence, its value is calculated using Equation (B.9): $U_{st} = 0{,}16 \times 120^{0,5} = 1{,}75$ W/K. As the solar storage tank is situated in the heated space of the house, θ_a = 20 °C. The ratio $Q_{W,sol,out,m}/Q_{W,sol,us,m}$ is derived from Table A.3. With this information, the thermal loss from the solar storage tank is calculated according to Equation (17). Table A.5 lists the results. The annual thermal loss of the storage tank is 228 kWh.

Thermal losses from the pipes between the solar storage tank and the back-up heater can be calculated with Equation (B.10). Table A.5 lists the results of the calculations. The annual thermal loss of the pipes is 19 kWh.

Table A.5 — Monthly values of the thermal losses of the solar storage tank and the pipes between storage tank and back-up heater

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
$Q_{W,sol,st,ls,m}$ [kWh]	0	2,3	18,6	27,0	33,9	36,8	34,8	37,9	23,5	12,8	0	0	**228**
$Q_{bu,dis,ls,m}$ [kWh]	0	0,2	1,6	2,3	2,8	3,1	2,9	3,2	2,0	1,1	0	0	**19**

A.2.7 Determination of the recoverable losses of the thermal solar system

Part of the auxiliary energy consumption and the thermal losses of the thermal solar system are recoverable and can be attributed to space heating of the house during the heating season, according to B.8:

— 50 % of the auxiliary energy consumption;

— 100 % of the thermal losses of the solar storage tank and the pipes between the solar storage tank and the back-up heater, as both the solar storage tank and the back-up heater are located in the heated part of the house.

Table A.6 lists the recoverable losses. The annual recoverable losses are 42 kWh.

Table A.6 — Monthly values of the recoverable losses of the thermal solar system

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
$Q_{sol,aux,rbl,m}$ [kWh]	0 5	0 8	1 7							1 3	0 7	0 4	
$Q_{sol,st,ls,rbl,m}$ [kWh]	0	2 3	18 6							12 8	0	0	
$Q_{bu,dis,ls,rbl,m}$ [kWh]	0	0 2	1 6							1 1	0	0	
$Q_{sol,ls,rbl,m}$ [kWh]	0 5	3 3	21 8							15 1	0 7	0 4	**42**

A.3 Solar combisystem

A.3.1 General

The second example presents a solar combisystem with 8,4 m^2 solar collector area and 800 litres solar storage tank. The top 200 litres of the storage tank is heated by back-up for domestic hot water. For space heating, the storage tank acts as preheat system, i.e. preheated water is heated by back-up before it enters the distribution system. Back-up heat is available at all times due to regulations with respect to microbiological safety of the domestic hot water. The back-up heater includes a pump for both heat distribution in the space heating loop and transport of back-up heat into the 200 litres top of the storage tank for domestic hot water. Typical operation time of the pump in conventional combisystems (without solar) with corresponding functionality is 1 000 hours per year and the distribution over the year follows the heat use. Power of the pump in the back-up part is 70 W. Properties of the solar collector, collector loop and pump are the same as in the first example. So are collector tilt and storage tank location.

The system is applied on and in a single family house with an annual space heating use of 100 kWh/m^2 floor area and 140 litres per day hot water draw-off based on a temperature step from 15 °C to 65 °C. There is a low temperature heat distribution system for space heating; its design temperature is 40 °C. The house is located in Zürich. Table A.7 lists the monthly values of average outside air temperature and solar irradiance and irradiation in the collector plane. Yearly average cold water temperature is 9,7 °C.

The objective is to determine the thermal performance of this solar combisystem. Calculation of the thermal performance follows the steps given in 6.3.

Table A.7 — Monthly values of average outside air temperature and solar irradiance and irradiation in a plane with a tilt of 45° facing South for Zürich (see B.4 and B.5).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
θ_o [°C]	0,1	0,5	4,8	8,0	12,5	15,2	18,8	18,1	14,5	9,9	4,1	1,6
I [W/m^2]	72	105	141	164	183	190	214	204	171	121	72	57
$E_{sol,in}$ [kWh/m^2]	54	71	105	118	136	137	159	152	123	90	52	42

A.3.2 Determination of the heat use

The daily hot water use is 140 litre × 1 kg/litre × 4180 J/(kgK) × 50 K = 8,13 kWh/day. Again, thermal losses of the pipes between back-up heater and tapping points are assumed to be 10 % of the heat use applied, corresponding to 0,81 kWh/day. Space heating use involves the other major input to the calculation method. Table A.8 lists the monthly values of heat use for domestic hot water and heat use for space heating as well as ratios of these heat uses to the sum of both. The heat use ratios P_W and P_H are needed for subsequent calculation of the thermal solar output.

Table A.8 — Monthly values of heat use for domestic hot water and for space heating as well as contribution of these uses to the sum of both

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
$Q_{W,sol,us,m}$ [kWh]	277	250	277	268	277	268	277	277	268	277	268	277
$Q_{H,sol,us,m}$ [kWh]	2 943	2 357	1 748	993	260	0	0	0	118	969	2 167	2 686
P_W [-]	0,09	0,10	0,14	0,21	0,52	1,00	1,00	1,00	0,69	0,22	0,11	0,09
P_H [-]	0,91	0,90	0,86	0,79	0,48	0	0	0	0,31	0,78	0,89	0,91

A.3.3 Determination of system data

Most system data needed for determination of X, Y and $Q_{sol,out}$ are available. The storage tank capacity correction factor should be calculated: f_{st} = ((8,4 m^2 x 75 litre/m^2)/(800 - 200) litre)^{0,25} = 1,012. The collector loop efficiency factor is not known; it is taken from B.2. The unknown overall heat loss coefficient of the collector loop pipes is also taken from B.2. Then, the value of U_{loop} can be calculated as 3,723 + 0,0135 · 40 + (5 + 0,5 · 8,4)/8,4 = 5,358 W/(m^2K). Table A.9 lists all characteristics needed for the calculation of the thermal solar system output.

Table A.9 — System characteristics for calculation of the thermal solar system output

solar collector		collector loop		solar heat store	
A	8,4 m^2	η_{loop}	0,9	V_{sol}	600 litres
η_0	0,802 6	$P_{aux,nom}$	20 W	f_{st}	1,012
IAM	0,94				
U_{loop}	5,358 W/(m^2K)				

A.3.4 Determination of X, Y and thermal solar system output

Values of X, Y and $Q_{sol,out}$ are calculated twice, i.e. once for thermal solar output for domestic hot water and the other time for thermal solar output for space heating. $Q_{W,sol,out}$ and $Q_{H,sol,out}$, respectively, are determined for each month using the monthly heat use values from Table A.8 and the system characteristics as listed in Table A.9. Collector area is multiplied by P_W respectively P_H from Table A.8. Table A.10 presents the calculations for domestic hot water and Table A.11 presents the calculations for space heating. For the period June – August, calculated thermal solar output for domestic hot water is larger than the demand. Hence, the output has been maximized to the values of the demand. The annual system output for domestic hot water is 1 581 kWh and the annual system output for space heating is 1 534 kWh. In total, thermal solar output is 3 215 kWh/year.

Table A.10 — Monthly values of the domestic hot water use, X, Y and thermal solar output for domestic hot water for the solar combisystem

	$Q_{W,sol,us,m}$ [kWh]	X [-]	Y [-]	$Q_{W,sol,out,m}$ [kWh]
Jan	277	0,91	0,095	10
Feb	250	1,01	0,154	22
Mar	277	1,28	0,295	56
Apr	268	1,82	0,534	99
May	277	3,82	1,446	227
Jun	268	6,71	2,909	268
Jul	277	5,79	3,276	277
Aug	277	5,97	3,123	277
Sep	268	4,79	1,819	247
Oct	277	1,79	0,412	76
Nov	268	1,05	0,121	15
Dec	277	0,95	0,082	6
Year	**3 263**			**1 581**

Table A.11 — Monthly values of the space heating use, X, Y and thermal solar output for space heating for the solar combisystem

	$Q_{H,sol,us,m}$ [kWh]	X [-]	Y [-]	$Q_{H,sol,out,m}$ [kWh]
Jan	2 943	0,95	0,095	104
Feb	2 357	1,06	0,154	204
Mar	1 748	1,51	0,295	331
Apr	993	2,34	0,534	338
May	260	5,68	1,446	190
Jun	0	0,00	0,000	0
Jul	0	0,00	0,000	0
Aug	0	0,00	0,000	0
Sep	118	7,65	1,819	94
Oct	969	2,45	0,412	228
Nov	2 167	1,21	0,121	98
Dec	2 686	1,03	0,082	47
Year	**14 240**			**1 634**

A.3.5 Determination of the auxiliary energy consumption

The auxiliary energy consumption of the pump in the collector loop is calculated according to Equation (16) where the pump power is 20 W and the annual pump operation time is 2 000 h distributed over the months according to the solar irradiation in Table A.7. Values for the auxiliary energy consumption are listed in Table A.12. The annual total is 40 kWh.

Table A.12 — Monthly values of the auxiliary energy consumption of the pump in the collector loop

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
$W_{sol,aux,m}$ [kWh]	1,7	2,3	3,4	3,8	4,4	4,4	5,1	4,9	4,0	2,9	1,7	1,4	**40**

A.3.6 Determination of the thermal losses of the thermal solar system

The overall heat loss coefficient has not been measured, hence, its value is calculated using Equation (B.9): $U_{st} = 0{,}16 \times (800 - 200)^{0{,}5} = 3{,}92$ W/K. As the solar storage tank is situated in the heated space of the house, $\theta_{a,avg}$ = 20 °C. For space heating, the set point temperature is 40 °C. The ratio $Q_{W,sol,out,m}/Q_{W,sol,us,m}$ is derived from Table A.10 and the ratio $Q_{H,sol,out,m}/Q_{H,sol,us,m}$ is derived from Table A.11. With this information, the thermal loss from the solar storage tank is calculated twice according to Equation (17), i.e. first for domestic hot water and then for space heating. Table A.13 lists the results. The annual thermal loss of the storage tank is 715 + 142 = 857 kWh.

Thermal losses from the pipes between the solar storage tank and the back-up heater can be calculated with Equation (B.10). Table A.13 lists the results of the calculations. The annual thermal loss of the pipes is 34 + 33 = 67 kWh.

Table A.13 — Monthly values of the thermal losses of the solar storage tank and the pipes between storage tank and back-up heater

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
$Q_{W,sol,st,ls,m}$ [kWh]	4,4	9,4	23,7	41,8	95,5	124	138	135	104	32	6,2	2,6	**715**
$Q_{H,sol,st,ls,m}$ [kWh]	2,1	4,6	11,0	19,2	42,5	0	0	0	45,1	13,7	2,6	1,0	**142**
$Q_{W,bu,dis,ls,m}$ [kWh]	0,2	0,4	1,1	2,0	4,5	5,9	6,5	6,4	4,9	1,5	0,3	0,1	**34**
$Q_{H,bu,dis,ls,m}$ [kWh]	2,1	4,1	6,6	6,8	3,8	0	0	0	1,9	4,6	2,0	0,9	**33**

A.3.7 Determination of the recoverable losses of the thermal solar system

Part of the auxiliary energy consumption and the thermal losses of the thermal solar system are recoverable and can be attributed to space heating of the house during the heating season, according to B.8:

— 50 % of the auxiliary energy consumption;

— 100 % of the thermal losses of the solar storage tank and the pipes between the solar storage tank and the back-up heater, as both the solar storage tank and the back-up heater are located in the heated part of the house.

Table A.14 lists the recoverable losses. The annual recoverable losses are 522 kWh.

Table A.14 — Monthly values of the recoverable losses of the thermal solar system

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
$Q_{sol,aux,rbl,m}$ [kWh]	0,9	1,1	1,7	1,9	2,2				2,0	1,5	0,8	0,7	
$Q_{sol,st,ls,rbl,m}$ [kWh]	6,5	14,0	34,7	61,1	138				149	45,6	8,8	3,6	
$Q_{bu,dis,ls,rbl,m}$ [kWh]	2,3	4,5	7,7	8,8	8,3				6,8	6,1	2,3	1,1	
$Q_{sol,ls,rbl,m}$ [kWh]	9,6	19,6	44,1	71,7	149				158	53,0	11,9	5,3	**522**

A.3.8 Determination of the reduction of auxiliary energy consumption of the back-up heater

Contribution of solar heat to the heat use reduces auxiliary energy consumption of the pump in the back-up part of the system. The reduction corresponds to the fraction of the heat use covered by solar heat as indicated in Equation (22). Table A.15 lists the nominal operation time of the pump in the case of no thermal solar system, the fraction of nominal pump operation that is saved by the thermal solar system and the reduced auxiliary energy consumption based on the 70 W power of the back-up heater pump. Annual savings are 70,0 – 56,4 = 13,6 kWh.

Table A.15 — Monthly values of the nominal operation time of the back-up heater pump, the fraction of the nominal pump operation saved by the thermal solar system and the reduced auxiliary energy consumption of the pump

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
$t_{p,bu,nom,m}$ [hr]	184	149	116	72	31	15	16	16	22	71	139	169	**1 000**
$f_{sol,,m}$ [kWh]	0,05	0,10	0,20	0,35	0,79	1,00	1,00	1,00	0,91	0,26	0,06	0,03	
$W_{bu,aux,m}$ [kWh]	12,3	9,4	6,5	3,3	0,5				0,1	3,7	9,1	11,5	**56,4**

Annex B
(informative)

Informative values for use in the calculation methods

B.1 System type coefficients

The system type coefficients are given in Table B.1.

Table B.1 — System type coefficients

Correlation factors	Type of system	
	Water storage [a]	Direct solar floor [b]
a	1,029	0,863
b	-0,065	- 0,147
c	-0,245	-0,263
d	0,001 8	0,008
e	0,021 5	0,029
f [c]	0	0,025

[a] The collector array is connected to the storage tank. A set of correlation coefficients has been determined in the f-chart method for this system type (see [1]).

[b] The collector array is directly connected to the heating floor; the floor acts as both the storage tank and the heat exchanger. New set of correlation coefficients has been determined for this system type (see [3]).

[c] New correlation coefficient introduced to better fit with direct solar floor system.

B.2 Thermal solar system default values

B.2.1 General

In general, two types of default values are given:

— typical values – for use when the purpose is to make a calculation of a typical thermal solar system;

— penalty values – used for giving penalty to “unknown” components (i.e. systems and components not tested and/or certified) in order to encourage use of high quality data for the calculation.

NOTE These values are only given for general purpose. It is not necessary to define both types of values in national annexes.

B.2.2 Typical values

1) Efficiency of the collector loop η_{loop},

The typical efficiency of the collector loop η_{loop} is 0,9.

NOTE η_{loop} takes into account the influence of the heat exchanger.

η_{loop} can be calculated from:

$\eta_{loop} = 1 - \Delta\eta$

where

$\Delta\eta = (\eta_0 * A * a_1)/(U_{st})_{hx}$ (see ENV 12977-2)

and

η_0 is the zero-loss collector efficiency determined in accordance with EN 12975-2;

A is the collector aperture area [m^2];

a_1 is the first order heat loss coefficient of solar collector determined in accordance with EN 12975-2;

$(U_{st})_{hx}$ is the heat exchanger heat transfer value (U_{st}-value) [W/K].

2) Heat loss coefficient of the collector a

$a = a_1 + 40 \cdot a_2$

where

a_1 is the first order heat loss coefficient of solar collector determined in accordance with EN 12975-2;

a_2 is the second order heat loss coefficient of solar collector determined in accordance with EN 12975-2.

Typical values:

a_1 = 1,8 W/m²K (evacuated tubular collectors;

a_1 = 3,5 W/m²K (glazed collector;

a_1 = 15 W/m²K (unglazed collector;

a_2 = 0 W/m²K^2.

3) Overall heat loss coefficient of the collector loop pipes $U_{loop,p}$

$$U_{loop,p} = 5 + 0,5\ A \qquad [W/(m^2K)] \qquad (B.1)$$

where

A is the collector aperture area [m^2].

4) zero-loss collector efficiency η_0

The zero-loss collector efficiency η_0 is determined in accordance with EN 12975-2.

Typical value: $\eta_0 = 0,8$

5) Nominal power of solar pump $P_{aux,nom}$

$$P_{aux,nom} = 25 + 2A \qquad [W] \qquad (B.2)$$

where

A is the collector aperture area [m^2].

B.2.3 Penalty values

1) Efficiency of the collector loop η_{loop}.

The penalty efficiency of the collector loop η_{loop} is 0,8.

2) Heat loss coefficient of the collector a

$a = a_1 + 40 \cdot a_2$

where

a_1 is the first order heat loss coefficient of solar collector determined in accordance with EN 12975-2;

a_2 is the second order heat loss coefficient of solar collector determined in accordance with EN 12975-2.

If collector characteristics are not known, the following penalty default values are adopted:

a_1 = 3 W/m²K (evacuated tubular collectors);
a_1 = 6 W/m²K (glazed collector);
a_1 = 20 W/m²K (unglazed collector);
a_2 = 0 W/m²K^2.

3) Overall heat loss coefficient of the collector loop pipes $U_{loop,p}$

$$U_{loop,p} = 5 + 0,5\ A \qquad [W/(m^2K)] \qquad (B.3)$$

where

A is the collector aperture area [m^2].

4) zero-loss collector efficiency η_0

The zero-loss collector efficiency η_0 is determined in accordance with EN 12975-2.

Penalty value : $\eta_0 = 0,6$

5) Nominal power of solar pump $P_{aux,nom}$

$$P_{aux,nom} = 50 + 5A \qquad [W] \qquad (B.4)$$

where

A is the collector aperture area [m^2].

B.3 Storage tank capacity correction coefficient f_{st}

In the case of water storage tank, the storage tank correction coefficient f_{st} is given by:

$$f_{st} = (V_{ref} / V_{sol})^{0,25} \qquad [-] \qquad (B.5)$$

where

V_{ref} is the reference volume equal to 75 litres per m² of collector;

V_{sol} is the solar storage tank volume.

In the case of solar preheat system, V_{sol} equals V_{nom} (nominal volume).

In the case of solar-plus-supplementary system, the solar storage tank volume V_{sol} is given by:

$$V_{sol} = V_{nom} \cdot (1 - f_{aux}) \quad \text{[litres]} \quad \text{(B.6)}$$

where

f_{aux} is the fraction of the storage tank volume used for back-up heating;

V_{nom} is the nominal storage tank volume.

The effective fraction f_{aux} is calculated by:

$$f_{aux} = x \cdot V_{bu} / V_{nom} \quad \text{[-]} \quad \text{(B.7)}$$

where

V_{bu} is the back-up storage tank volume contained between the top of the tank and the bottom of the back-up element (electric element or heat exchanger)

x is the control coefficient equal to:

- 1 if the back-up is a permanent power supply;
- 0,7 night back-up;
- 0,3 emergency back-up.

The default value of f_{aux} is:

- 0,50 for a vertical tank;
- 0,66 for a horizontal tank.

B.4 Reference temperature θ_{ref}

θ_{ref} depends on the system and the application:

Space heating system:

θ_{ref} =100 °C

Domestic hot water systems:

$$\theta_{ref} = 11{,}6 + 1{,}18\ \theta_w + 3{,}86\ \theta_{cw} - 1{,}32\ \theta_{e,avg}\ \text{°C} \quad \text{(B.8)}$$

where

θ_w is the desired hot water temperature taken as equal to 40°C;

θ_{cw} is the mains water supply temperature [°C] according to Table B.2 (identical for each month);

$\theta_{e,avg}$ is the average outside air temperature for the considered period, [°C] according to Table B.2.

Table B.2 lists values of θ_{cw} and $\theta_{e,avg}$ for the reference locations/climates (informatively) used in the elaboration of solar domestic hot water and solar combisystem tests, such as in EN 12976-2 and ENV 12977-2.

Table B.2 — Annual average mains water supply temperature and monthly outside air temperatures for different European climates and locations (source for ambient temperatures: Meteonorm v5.0)

Location/ climate	θ_{cw} [ºC]	$\theta_{e,avg}$ [ºC]											
		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Athens (Gr)	17,8	9,3	9,8	11,7	15,5	20,2	24,6	27	26,6	23,3	18,3	14,4	11,1
Birmingham (UK)	3,2	3,2	5,3	7,6	10,7	14,0	15,8	15,5	13,3	10,1	6,1	4,3	9,1
Carpentras (F)	13,5	5,5	5,8	9,8	11,3	15,1	18,9	22,9	21,3	18,4	13,9	8,7	5,4
Davos (CH)	5,4	-5,1	-5	-1,6	1,5	6,1	8,9	12,5	11,8	8,9	5,3	-0,7	-3,4
Stockholm (S)	8,5	-2,8	-3	0,1	4,6	10,7	15,6	17,2	16,2	11,9	7,5	2,6	-1,0
Würzburg (D)	10,0	0,6	1,1	5,6	8,3	13,3	16,7	18,3	18,3	15	9,4	4,4	1,7
Zürich (CH)	9,7	0,1	0,5	4,8	8,0	12,5	15,2	18,8	18,1	14,5	9,9	4,1	1,6

B.5 Solar irradiance on the collector plane and incidence angle modifier

I_m is the average solar irradiance on the collector plane during the considered period expressed in W/m².

Three categories of orientation of collectors are possible:

1) where collectors face between south-east and south-west and are angled in the range from latitude-20° to latitude+5° from the horizontal and are not shadowed by any obstacles. The values for I_m are as given in Table B.3 below for different climatic zones;

2) for all other cases, the values for I_m are the values given in Table B.3 multiplied by a coefficient of 0,8, provided that the orientation of collectors is within the range of ± 90° of south (between east and west) and the average height of obstacles on the horizon is less than 20° (tilt angle is arbitrary);

3) for all other configurations, no account is taken of the solar installation (no influence on the building energy performance).

Table B.3 lists values of I_m for the reference locations/climates (informatively) used in the elaboration of solar domestic hot water and solar combisystem tests, such as in EN 12976-2 and ENV 12977-2.

Table B.3 — Monthly solar irradiance on a flat plane facing South with a tilt angle of 45° for different European climates and locations (source: Meteonorm v5.0)

Location/ climate	I_m [W/m^2]											
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec
Athens (Gr)	150	154	164	206	220	236	250	267	252	193	142	117
Birmingham (UK)	42	67	97	154	175	175	174	164	127	80	53	32
Carpentras (F)	141	163	208	220	234	255	270	267	238	177	138	119
Davos (CH)	173	215	251	249	231	217	229	217	208	195	153	141
Stockholm (S)	37	84	150	190	237	245	222	204	148	94	45	36
Würzburg (D)	67	108	145	184	204	209	210	200	177	121	67	53
Zürich (CH)	72	105	141	164	183	190	214	204	171	121	72	57

The incidence angle modifier IAM depends on the collector type. Default values are:

— for flat plate glazed collectors, IAM = 0;94;

— for unglazed collectors, IAM = 1,00;

— for evacuated tubular collectors with flat absorber, IAM = 0,97;

— for evacuated tubular collectors with circular absorber, IAM = 1,00.

B.6 Thermal losses of the solar storage tank

If the overall heat loss coefficient of the storage tank U_{st} is not known, it can be calculated by:

$$U_{st} = 0,16\ V_{sol}^{0,5} \quad \{W/K\} \tag{B.9}$$

where

V_{sol} is the solar storage tank volume [l].

B.7 Thermal losses of the distribution between the thermal solar system and the back-up heater

The thermal losses of the distribution between the thermal solar system and the back-up heater are calculated by:

if the pipes are insulated:

$$Q_{bu,dis,ls,m} = 0,02 \cdot Q_{sol,us,m} \cdot (Q_{sol,out,m} / Q_{sol,us,m}) \tag{B.10}$$

if the pipes are not insulated:

$$Q_{bu,dis,ls,m} = 0,05 \cdot Q_{sol,us,m} \cdot (Q_{sol,out,m} / Q_{sol,us,m}) \tag{B.11}$$

B.8 Recoverable part of system losses

The recoverable part of the auxiliary energy consumption of the pump is 50 %.

The recoverable part of the thermal losses of the solar storage tank and the thermal losses of the distribution between the thermal solar system and the back-up heater could be recovered only during the heating season. During the heating season, the recoverable part of these losses is:

— 100 % if the component is installed in the heated space;

— 50 % if the component is installed in an un-heated space;

— 0 % if the component is installed outside.

Annex C
(informative)

Product classification

C.1 Solar collectors

Characteristics are:

A	collector aperture area,	(m²);
η_0	zero-loss collector efficiency,	(-);
a_1	first order heat loss coefficient of solar collector.	(W/m²·K);
a_2	second order heat loss coefficient of solar collector (temperature dependence).	(W/m²·K²);

η_0, a_1 and a_2 are determined according to EN 12975-2.

C.2 Solar hot water heaters

This applies to factory made solar hot water heaters sold as complete and ready to install kits, with fixed configurations and assessed as a whole according to EN 12976-2.

Where no classification is given, a solar hot water heater can be defined by its components:

— collector;

— storage tank;

— collector loop pipework.

Characteristics are:

A	collector aperture area	(m²);
V_{nom}	nominal storage tank volume	(litres).

NOTE The following characteristics are intermediate parameters calculated according to ISO/FDIS 9459-5, but not indicated on the official test results given in EN 12976-2:

A_C*	effective collector loop area	(m²);
C_{st}	thermal heat capacity of the storage tank	(MJ/K);
U_C*	effective collector heat loss coefficient	(W/m²·K);
f_{aux}	fraction of the storage tank volume used for back-up heating,	(-).

C.3 Storage tanks

Characteristics are:

V_{nom}	nominal storage tank volume	(litres);
U_{st}	overall heat loss coefficient of the storage tank	(W/K).

If U_{st} is not known, but the cooling constant C_C (Wh/l·K·day) is, the following equation is used:

$$U_{st} = C_C \cdot V_{nom} / 24 \qquad [W/K]$$

NOTE This equation applies only if the cooling constant of the storage tank is less than or equal to the default value of the hot-water bulb, i.e.: $C_C \leq 4{,}2\ V_{nom}^{-0,45}$.

V_{sol} solar storage tank volume, obtained from the following equation:

$$V_{sol} = V_{nom} \cdot (1 - f_{aux}) \qquad [litres]$$

where

f_{aux} is the fraction of the storage tank volume used for back-up heating:

- f_{aux} may be determined directly by tests carried out in accordance with EN 12976-2;
- f_{aux} is zero when the bulb does not have an integrated back-up.

Annex D
(informative)

Savings calculation

To determine the resulting influence of a thermal solar system on the energy performance of a building, i.e. the savings due to the installation of a thermal solar system, two calculations have to be performed:

- C0: Calculation of the primary energy consumption of the building without the thermal solar system;
- C1: Calculation of the primary energy consumption of the building with the thermal solar system.

The energy savings due to the installation of the thermal solar system is determined as the primary energy consumption of the building without the thermal solar system (C0) minus the primary energy consumption of the building with the thermal solar system (C1):

$$S_{sol} = C0 - C1 \tag{D.1}$$

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